



	Unclassified	
	TREX ENTERPRISES	
Ballistic Missile Defense Organization (BMDO) Optical Target Characterization & Innovative Science & Technology Experimentation Facility (ISTEF) Program		
BMDO Science & Technology Agent: Michael Lovern SPAWAR Systems Center, San Diego D853 Voice: (619) 553-3724 Fax: (619) 553-6121 Email: lovern@spawar.navy.mil		ISTEF Site Manager: Mac Monroe Nichols Research Corp. Voice: (407) 853-5285 Fax: (407) 853-5299 Email: monroem@nichols.com
Distribution Statement A: Approved for public release; distribution is unlimited		
		
Unclassified		

ABSTRACT

The Optical Target Characterization Program supports research and development in the area of electro-optical science and technology for missile defense. The objective is to develop and apply innovative state-of-the-art active and passive optical sensors and techniques to demonstrate concepts relating to BMDO requirements such as booster typing, tracking, target discrimination, aimpoint selection and kill assessment. To achieve this objective, the Program maintains the Innovative Science and Technology Experimentation Facility (ISTEF), located at Kennedy Space Center (KSC), FL, and conducts research and development into novel coherent laser radar and laser communications systems, and electro-optical materials technologies. The Optical Target Characterization Program is funded by the Ballistic Missile Defense Organization and managed by the Space and Naval Warfare Systems Center, San Diego.

19991116 007

	Unclassified Outline	 Systems Center San Diego
<ul style="list-style-type: none"> ● Overview ● ISTEf ● Plume Characterization ● Dual-mode Experiment on Bowshock Interactions (DEBI) ● CREOL: <ul style="list-style-type: none"> ● Antenna Coupled Focal Plane Array ● PhotoThermal Refractive Glass ● Summary 		
Unclassified D:\ISTEF\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 2		

The presentation will consist of:


An **overview** of some of the goals and objectives, and the various research and development Projects being conducted on the Program will be presented.

An overview of the **BMDO's Innovative Science & Technology Experimentation Facility (ISTEF)** will be presented which will include the physical location, key equipment which are part of it's unique capabilities, and an example of the type of data collected.

A brief description of the efforts being conducted to characterize missile **plume signatures** will be presented that includes high resolution multispectral imagery collected by ISTEf, laser radar cross section data, and is compared against existing signature codes to determine their accuracy and limitations.


The **Dual-mode Experiment on Bowshock Interactions (DEBI)** flight will be discussed briefly as this will be covered in more detail in a later paper by Dr. Dave Mann (ARO). However, DEBI is a collaborative effort between the Optical Target Characterization and the Missiles and Aerothermochemistry Programs to conduct a missile flight experiment aimed at collecting measurements of the optical environment encountered by vehicles travelling at hypervelocity speeds.

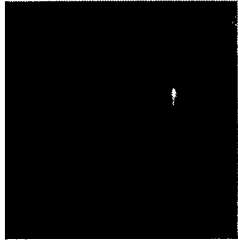
Additionally, an overview of the materials research being conducted into **Antenna Coupled Infrared Focal Plane Arrays (ACIRFPA)** for developing novel uncooled IR FPA's which utilize antenna's to couple radiation into a sub-wavelength size bolometers, and **Photo-Thermal Refractive (PTR) Glass** aimed at developing a holographic material using silicate glass which would have the unique properties of being thick, and permanent and could combine and replace existing optics.



Unclassified


OPTICAL TARGET CHARACTERIZATION (ISTEF*)



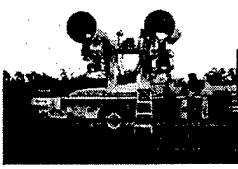


QWIP LWIR Imagery of HERA during reentry

- Apply state-of-the-art active and passive optical sources, sensors and techniques to develop and demonstrate innovative scientific concepts relating to BMDO missions:
 - Booster typing
 - Tracking
 - Target discrimination
 - Aimpoint selection
 - Kill assessment
- Support research in:
 - Passive UV† - LWIR§ imaging/tracking
 - Active plume / hardbody signatures
 - Laser radar / active imaging
 - Sensor data fusion

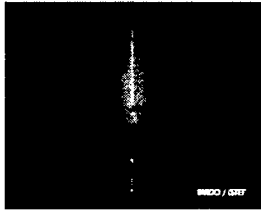


DUNDEE Narrow field of view (NFOV) MWIR reentry image; altitude = 114 km & range = 118 km



KTM at WFF during Red Tigris III

* ISTEF: Innovative Science & Technology Experimentation Facility
 † UV: Ultraviolet
 § LWIR: Long Wavelength InfraRed
 ‡ MWIR: Mid-Wavelength InfraRed



Laser illuminated imagery of Titan K-24 (24 Jan 97)


Unclassified

D:\ISTEF\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 3

The overall goal and objective of the Optical Target Characterization Program is to perform research, development, and demonstration of new electro-optic sensors, techniques and concepts for ballistic missile defense. These are generally aimed at the BMD problems such as target tracking, identification, aimpoint selection and kill assessment.


Research areas include: new sensors and conceptual techniques in passive multispectral imagery from as low as the UltraViolet (UV) thru to the Long Wavelength InfraRed (LWIR); Active (laser radar) direct detection and coherent detection laser radar; and sensor data fusion of multispectral image data with laser radar data and RF radar data for better metric tracking and potentially for signature analysis;

The ISTEF also provides support for Major Defense Acquisition Programs such as THAAD and other programs. This support is generally for the purpose of providing high resolution, calibrated imagery for use in determination of flight performance, signature collection, and diagnostics. ISTEF now also has the capability to collect passive as well as active signature data using it's mobile optical tracking system(s). The picture of the tracking mount in the lower left corner is of the primary mobile data collection asset with twin 24" telescopes and the other images on the slide are examples of ISTEF data.



Unclassified

BMDO / ISTE



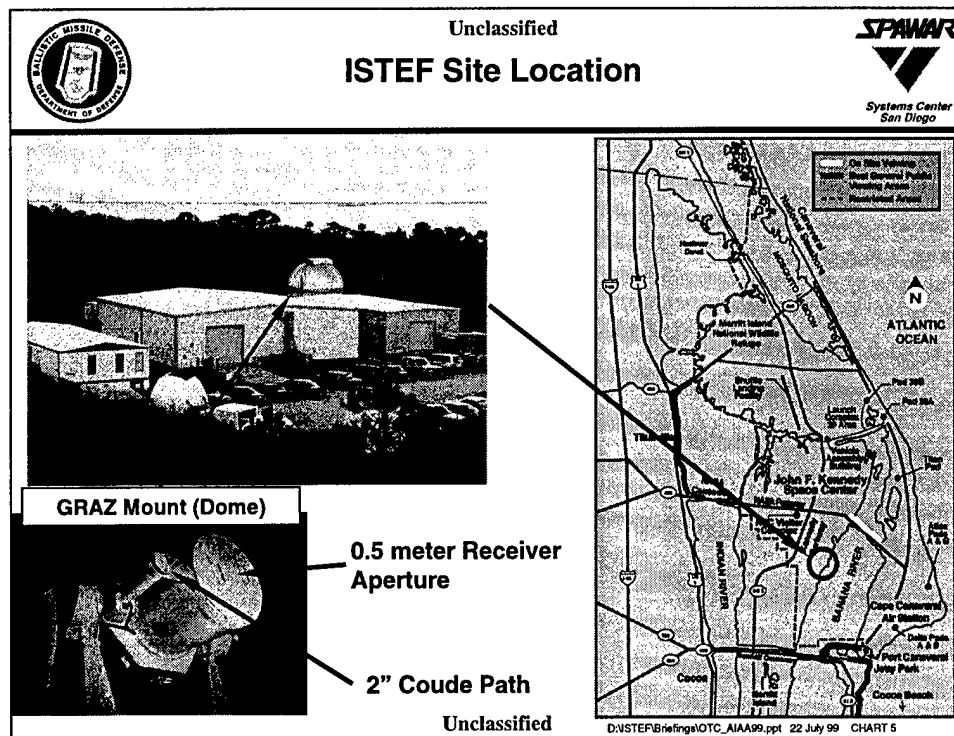
- **ISTEF is a BMDO/TOR Asset:**
 - The Optical Target Characterization Program supports research and development in the area of passive and active electro-optical technology for missile defense. The ISTE is an electro-optical facility for conducting research, development, test and evaluation on new sensor technologies and algorithms in the area of missile defense.
 - ISTE is Government owned and managed, and is operated and maintained by on site contractors
 - Visiting experiments are welcome and encouraged
- **Points of Contact:**
 - Program Manager: Mike Lovern
 SPAWARSYSCEN San Diego D853 (619) 553-3724
 Attn: Michael Lovern
 53490 Dow Street
 San Diego, CA 92152-5742
 - ISTE/NRC Manager: Mac Monroe (NRC)
 - Principal Investigator, Passive Sensor Experiments: Al Tietjen (NRC)
 - Principal Investigator, Active Sensor Experiments: John Stryjewski (NRC)
 BMDO/ISTEF (407) 853-5285
 Bldg TRM-037
 Kennedy Space Center, FL 32899 Unclassified

D:\ISTEF\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 4

The ISTE Program is managed for BMDO by the U S Navy Space and Naval Warfare Systems Center (SPAWARSYSCEN) San Diego. Mike Lovern is our Program Manager there, and manages ISTE as a part of the Optical Target Characterization Program for BMDO. Mike can be reached at the above address.

I am the Nichols Research ISTE Manager in Florida. I can be reached at the site, at the address and phone numbers indicated on the slide.

ISTEF conducts signature measurements of ballistic missiles using both passive and active optical sensors. Mr. Al Tietjen acts as Principal Investigator for Passive Experiments and Dr. John Stryjewski acts as Principal Investigator for Active Experiments. You will hear from both of these gentlemen later in this session, with discussions of some of our efforts at ISTE. Both of them can also be reached at the site address above.





The ISTEF Site functions as a DoD tenant organization on the Air Force Eastern Range (ER) operated by the 45th Space Wing at Cape Canaveral Air Station. However, ISTEF is physically located inside the boundaries of the NASA Kennedy Space Center (KSC) on Merritt Island.

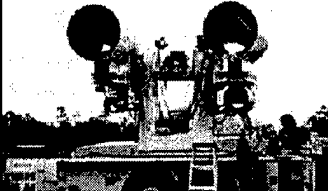
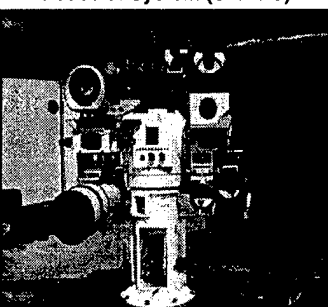
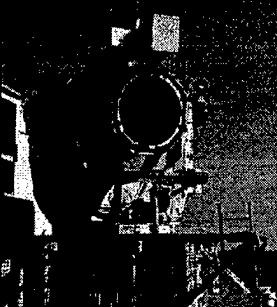
The ISTEF is located in a remote area of KSC, near another DoD installation, the main ER telemetry site, Tel-4, as shown on the map on this slide.

ISTEF is located approximately 9 km from the two Delta launch pads at Complex 17, approximately 11 km from the two Atlas launch pads at Complex 36, approximately 12 km from the Spaceport Florida launch complex 46 used for Athena launches, approximately 15 km from the Titan pad at Complex 40, and over 20 km from the two Shuttle launch pads at Complex 39.

There is one telescope, the half-meter aperture "Graz" system shown in this slide, permanently installed at the ISTEF site.

Unclassified
**ISTEF Mobile Optical Tracking Mounts and
Typical Configurations**

Kineto Tracking Mount (KTM)	Small Transportable ISTE Pedestal System (STRIPS)	NRL Transportable Mount
 <p style="text-align: center;">TELESCOPES</p> <ul style="list-style-type: none"> ● (2) - 24" UV - LWIR NFOV <ul style="list-style-type: none"> ● FOV: ~2 mrad ● 12" UV - NIR NFOV <ul style="list-style-type: none"> ● FOV: 4.2x3.1 mrad, or 2.9x2.2 mrad ● 7" Vis - NIR MFOV <ul style="list-style-type: none"> ● FOV: 4.2x3.1 mrad, or 2.9x2.2 mrad ● 3" Vis WFOV <ul style="list-style-type: none"> ● FOV: ~25 mrad 	 <p style="text-align: center;">TELESCOPES</p> <ul style="list-style-type: none"> ● (2) - 12.5" UV - LWIR <ul style="list-style-type: none"> ● FOV: Afocal, 2.6 mrad, or 1.3 mrad configurations ● 7" Vis - NIR MFOV <ul style="list-style-type: none"> ● FOV: 4.2x3.1 mrad, or 2.9x2.2 mrad ● 3" Vis WFOV <ul style="list-style-type: none"> ● FOV: ~25 mrad 	 <p style="text-align: center;">TELESCOPES</p> <ul style="list-style-type: none"> ● 30" UV - LWIR <ul style="list-style-type: none"> ● FOV: 1 mrad ● 12" UV - NIR NFOV ● 10" UV - LWIR MFOV <ul style="list-style-type: none"> ● FOV: 10.9 mrad ● 3" Vis WFOV


Unclassified

D:\ISTEF\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 6

In addition to the permanent telescope installation, ISTE has three mobile tracking mounts, all of which can be operated at the ISTE site, or moved to other locations within the KSC/Cape Canaveral area as required for data collection.


These mobile resources can also be deployed to other remote locations as required to support BMDO and other Government Agency requirements. ISTE equipment has been deployed to other test ranges, including Dugway, WSMR, Wallops, and Woomera, as well as to other sites for special collections, including Dam Neck Naval Station, Vieques Island Puerto Rico, and Broome, Western Australia.

ISTEF has a number of telescopes of various sizes which can be mated with optical instruments as required on a mission-by-mission basis. A significant number of these telescopes are "all reflecting" and can be used for instruments operating outside the visible spectrum either in the Infrared or the ultraviolet. Some of these telescopes are listed in this figure. A more complete listing is available from the ISTE site. These telescopes can also be mated with "visiting experiment" sensors for developmental testing.




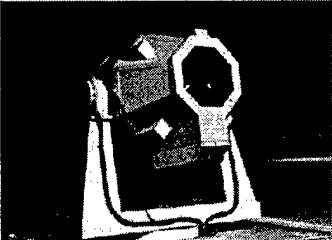
Unclassified

Rapid Optical Beam Steering (ROBS) Sensor



- **MWIR Narrow Field-of-View Camera**
 - 0.5 meter aperture w/ 28° Field of Regard
 - FOV: 5 mrad
 - Pixel Resolution: 14.7 μ radians
 - InSb 256 x 256 FPA
 - Framerate: 250Hz
- **MWIR Wide Field-Of-View Camera**
 - PtSi 512 x 512 FPA
 - Framerate: 30Hz
 - FOV: 14° x 11°
 - Pixel Resolution: 400 μ radians
- **Upgraded Optics Provides Capability For Visible Through LWIR Sensors**






- **Laser Radar**
 - Previous CO₂ laser radar is being replaced with solid state eye-safe direct detection system
 - $\lambda = 1.5$ micron
 - Pulse Energy ~ 100 mJ
 - Pulse Repetition Frequency = 20 Hz
 - Range Resolution (expected) = 2 meters
 - Accommodations made to allow alternate use of 1.06 micron wavelength
- **Multiple Target Tracking**
 - Simultaneous track of up to four targets has been demonstrated

Unclassified

D:\STEP\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 7


The Rapid Optical Beam Steering (ROBS) System is a unique mobile optical tracking system. ROBS is a multiple object tracking system which can track up to 4 objects within a wide field-of-regard (approx. 28°). ROBS has a wide-field-of-view (WFOV) MWIR camera which is used for target acquisition. The operator designates the target(s) to be tracked using the WFOV camera imagery. The system then uses the WFOV track to slew the narrow-field-of-view "stinger" and then begins tracking in the NFOV MWIR camera.

Over the past year, ROBS has been undergoing upgrades to the optical system. The original CO₂ ladar has been removed for replacement with a solid state eye safe ladar operating at 1.5 microns. This change in ladar wavelengths necessitated the replacement of existing refractive optics in the "secondary" system. The decision was made to redesign the system to use all reflective optics in order to also accommodate sensors/cameras operating from Visible through LWIR. The new ladar is a direct detection system and will have a range resolution on the order 2 meters at a repetition frequency of 20 Hz and should work out to significant ranges; However, provisions have been made to allow for use of the higher energy 1.06 micron wavelength in order to increase the potential range capabilities.

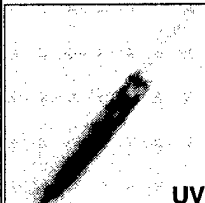


Unclassified

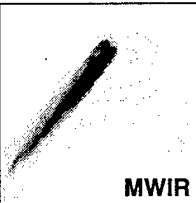
Atlas Active / Passive Data Collection



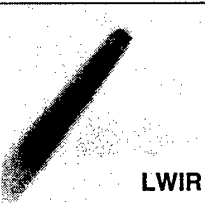
- **ISTEF Unique Mobile Data Collection**
 - Simultaneous high resolution, calibrated multispectral imagery
 - Ultraviolet (UV)/Visible, Mid Wavelength Infrared (MWIR), & Long Wavelength Infrared (LWIR)
 - Recent Atlas data is best simultaneous high resolution imagery to date
 - Data impacts current state of models
 - Capability to collect direct detection laser backscatter data
 - Simultaneous collection of active and passive data important for future seekers and detection systems (DITP and Navy airborne IRST Programs are examples of each)
- **Liquid Fueled Atlas II Collections**
 - Unclassified liquid fueled (Lox-Kerosene) surrogate
 - Large number of targets of opportunity at KSC




UV



MWIR



LWIR




Atlas plume / hardbody
laser backscatter.

Atlas multispectral plume imagery. Unclassified D:\NSTEP\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 8

One of the unique capabilities of ISTEF is the ability to collect simultaneous calibrated passive optical imagery in multiple spectral bands and at the same time, probe the plume and missile hardbody with active laser radiation to provide backscatter data for correlation with the passive imagery.

ISTEF has a transportable laser system, so it is possible to do these collections either from our fixed site or from a remote location.


Most current TMD threats utilize liquid propellant technology, although there are some potential future TMD threats which will use solid propellants. Another ISTEF advantage is that the Eastern Range is the only location in the US where liquid propellant missile systems are launched on a regular basis. The Atlas II and (soon) Atlas III boosters use all liquid cryogenic (LOX/RP-1) booster engines with no strap-on SRBs, and thus provide a LOX-kerosene type plume for our signature measurements.



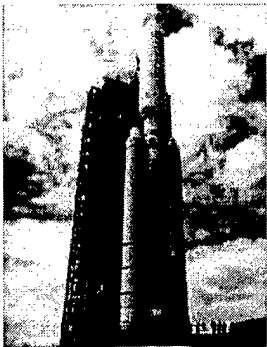
NAVY AIR STATION
DEPARTMENT OF DEFENSE

Unclassified

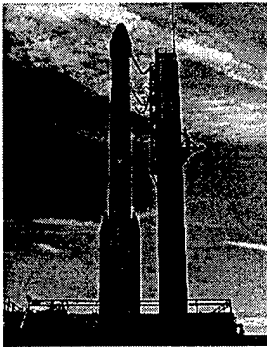
Cape Canaveral "Targets" of Opportunity



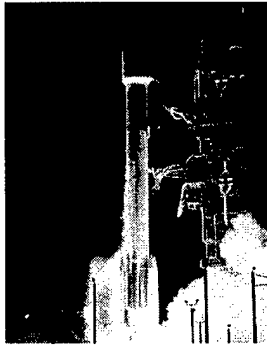
SPAWAR
Systems Center
San Diego



Titan IV-B



Delta II



Atlas IAS

	Titan IVB	Delta II	Atlas IAS
Total Diameter (m)	3 - 5	2.4 - 2.9	3
Total Height (m)	65	38.3	47.5
Booster Diameter (m)	3.2	1	1
Booster Height (m)	34.3	13	9.1
Number of Boosters	2	9, 4 or 3	4


Unclassified

D:\STEP\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 9

The largest number of launches from the Eastern Range are Delta and Atlas space boosters. The Delta II and Delta III missiles lift off with a number of solid propellant SRBs burning and producing a plume dominated by AIO. As indicated on the previous slide Atlas II and Atlas III boosters are all liquid at liftoff, although with multiple engine configurations that produce complex plumes which are not well modeled by the current plume codes. Atlas IAS missiles have strap-on SRBs and produce plumes similar to the Delta II missiles.


Occasional all solid Athena launches from Complex 46 provide single nozzle solid motor plumes for signature collection, while Titan IVB missiles from Complex 40 lift off on two large solid boosters with the hypergolic liquid Titan first stage not igniting until the SRBs burn out after two minutes of flight.

Thus ISTEf has available a combination of all liquid plumes, mixed SRB and liquid engine plumes, and all-solid plumes for signature collection and analysis.



Unclassified

ISTEF Visiting Experiments



<ul style="list-style-type: none"> ● Motivation <ul style="list-style-type: none"> ● Infrastructure ● Large number of (unclassified) targets of opportunity ● Expertise ● Laser radiation approval <ul style="list-style-type: none"> ○ 1km & 10km ranges ● FY-98: <ul style="list-style-type: none"> ● BMDO/TORI (JPL) Computed Tomography Imaging Spectrometer (CTIS) <ul style="list-style-type: none"> ○ Collects two-dimensional imagery and spectra simultaneously ● BMDO/TOR (KTAADN) Passive Ranging System <ul style="list-style-type: none"> ○ Data collected during THAAD FT-08 ● BMDO/TORI (CREOL) Coherently combined receiver laser radar/communications system 	<ul style="list-style-type: none"> ● Potential FY-99: <ul style="list-style-type: none"> ● BMDO/TOS Discriminating Interceptor Technology Program (DITP) <ul style="list-style-type: none"> ○ Three-dimensional laser radar imaging system ○ Integrated Brassboard System ● BMDO/TORI (JPL) Computed Tomography Imaging Spectrometer (CTIS) <ul style="list-style-type: none"> ○ Collects two-dimensional imagery and spectra simultaneously ● Joint BMDO/Israel Data Exchange Agreement <ul style="list-style-type: none"> ○ ISTEF/Israeli unclassified collections to support DEA Plume Modeling effort ● BMDO/TORI (JPL) Delta-doped CCD ● NRC Passive MWIR Polarization Sensor ● BMDO/TORI (CREOL) Antenna Coupled Focal Plane Array
--	--


Unclassified

D:\ISTEF\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 10

In addition to our own ongoing program of active and passive signature measurements, ISTEF is able to host visiting passive and active experimenters for experimental collections both at the Eastern Range, and at other locations by the deployment of one of our mobile tracking systems.

This slide lists some of the current and planned visiting experiments here at ISTEF. The Computed Tomography Imaging Spectrometer is an excellent example of a new technology which has great potential for future BMD applications as well as many other applications. At this early stage in the instrument development, a bright source was needed as a test target. By bringing the instrument to ISTEF to collect plume spectra, useful data were collected both for instrument development and analysis and for BMD plume signature applications.


The ISTEF staff's unique experience in field measurements and data collection can be very helpful to experimenters. For example, we have conducted a large number of active laser signature measurements and are well versed in the laser safety and documentation requirements for field collection, and can expedite that process for new experimenters.



PAFIC MISSILE DEFENSE
DEPARTMENT OF DEFENSE

Unclassified


Plume Characterization Program



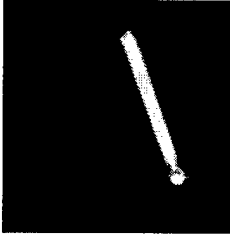
SPAWAR
Systems Center
San Diego

- **Plume Modeling / Predictions**
 - Demonstrate the utility and limitations of CFD codes to predict flow features
 - Model limitations for predicting plume optical radiation
 - Complimentary research efforts being conducted under BMDO/Israeli Target and Boost Phase Signatures DEA
- **Application to Boost Phase Intercept Systems For Identification, Discrimination, Plume-Hardbody Handover**
 - Missile discrimination based on plume signature
 - BMDO/Israeli Arrow Program
 - Airborne Laser (ABL)
 - Navy TBMD
- **New Technologies/Techniques to Exploit Plume Characteristics**
 - Simultaneous multispectral passive data: total radiance, plume spatial structure, multispectral content, etc.
 - Active LADAR: laser backscatter & doppler signatures (direct detection & coherent)

**Measured vs Predicted MWR Plume Image
(40 km altitude)**



ISTEF MWR
Imagery



CFD (QSP)




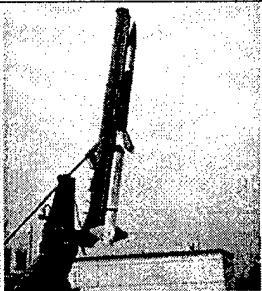
Unclassified

D:\STEF\Brling\OTC_AIAA99.ppt 22 July 99 CHART 11

The Plume Characterization Program is aimed at collecting calibrated, high resolution multispectral imagery of rockets in flight and comparing the measured results with those generated by current models. Models for predicting the plume radiance and particularly its spatial structure are being investigated. As can be seen from the figures on the right, using a commercially available CFD code yields a result very different from the measured results. The research being accomplished under this effort is complimentary to similar efforts in Israel for the boost phase intercept program. In fact, Israel is quite interested in collaboration with this program.


Applications and impact of this research is the boost phase intercept problem where the plume signature is used to help with discrimination and ultimately the desire is for identification. Obviously, this data is important to Programs such as the Arrow and ABL, but also for the planned Navy Airborne InfraRed Search & Track (IRST) system. The Airborne IRST is envisioned to provide launch detection and tracking and eventually will have a laser radar component.

As a further improvement in the signature collection area, ISTEf has developed the capability to collect multi-wavelength (0.532 & 1.06 micron) laser radar backscatter measurements. These so-called laser radar cross section (LRCS) measurements coupled with the multispectral passive data should yield valuable insight into the plume signature.


	<p>Unclassified</p> <h2>Dual-mode Experiment on Bowshock Interactions (DEBI)</h2>		
	<p>OBJECTIVES</p> <ul style="list-style-type: none"> • Perform science experiments to verify ability to see through window and hot gas shock layer at hypersonic velocities • Characterize onboard optical environment for dual-mode UV-IR seeker <ul style="list-style-type: none"> • BMDQ/TORI seeker concept • Improve predictive power of hypersonic aerothermochemical modeling <ul style="list-style-type: none"> • Previous Bowshock I & II experiments reduced UV errors from 10^5 to 10 		
	<p>Unclassified</p> <p><small>D:\STEF\Briefing\OTC_AIAA99.ppt 22 July 99 CHART 12</small></p>		

The Dual-mode Experiment on Bowshock Interactions (DEBI) is a rocket flight experiment to characterize the optical environment seen by an interceptor travelling at hypersonic velocities. At these velocities, window heating and a heated shock layer flowing around the forebody present significant challenges for a seeker which must operate in the atmosphere. The idea to utilize a second seeker band operating in the UV-VIS region has been offered as a potential solution to this problem. This flight test is designed to help determine the predictive capability of the flowfield models and to support the concept of a second band at a shorter wavelength. This is the third such flight, but will collect near infrared through mid wavelength infrared data for use in improving the current models. Previous Bowshock flights significantly reduced the modeling error from 10^5 to a factor of 10.


The experiment plan is to fly a vehicle forebody similar to the AIT shape, so that it is more representative of an interceptor. The primary experiment is to be conducted between 40 and 70 km on the upleg with the vehicle travelling at approximately 3.5 km/sec. A Terrier-Malemute stackup was chosen following a search to find an inexpensive launch vehicle which could provide the required speed at these altitudes. The optical payload will consist of fourteen radiometers looking out the side window: Six short wavelength infrared (SWIR) and eight in the MWIR each with a spectral filter at approximately 0.2 micron spacing across the bands; a sixteen channel IR spectrometer operating at 1.0 - 3.0 microns looking out the side window; and two UV detectors, one looking forward at the stagnation point and one looking out the side of the forebody;



Unclassified
Research Area:
Antenna Coupled Infrared Focal Plane Array



UCF
Systems Center
San Diego



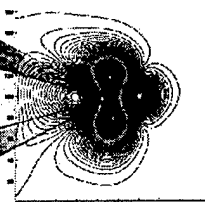

SPAWAR
Systems Center
San Diego

OBJECTIVE:

- Develop & Demonstrate use of antennas to couple Infrared (IR) radiation into subwavelength-sized sensors
 - Polarization and wavelength tunable IR detectors are possible at pixel level with no moving parts
 - Advantage is separation of radiation-collection and radiation-sensing functions providing system flexibility not typically attainable in IR
 - Uncooled detectors

FABRICATION TECHNIQUE:

- Direct-write electron beam lithography onto Si Substrate
 - Cornell Nanofabrication Facility
 - Dipoles are approx. $0.2\mu \times 10\mu$ features
- Antenna design to be optimized in future
 - Pattern
 - Materials

ANTENNA COUPLED FPA BENEFITS:

- Polarization and/or selection on a frame-by-frame basis without moving parts
- Provide enhanced target discrimination against background clutter
- Target feature extraction
- Countermeasure discrimination
- Clutter removal
- Operations at room temperature eliminate cryo cooler requirements
- Many uncooled MW/LWIR low power applications


Unclassified

D:\STEP\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 13


The objective of the research on Antenna Coupled Infrared Focal Plane Arrays (ACIRFPA's) is to demonstrate the use of lithographic antennas for coupled optical radiation into an uncooled bolometric device. The benefit of these devices is that their polarization and center wavelength response can be tuned electronically without any moving parts. These devices should also be much faster and more sensitive than current uncooled devices.


The ACIRFPA's are fabricated on silicon substrates using direct-write electron beam lithographic techniques at the Cornell Nanofabrication Facility (CNF). The images in the upper right are examples of these devices. The image on the left is a simple dipole design with an antenna length and width of 10 by 0.2 microns. The active area, bolometer, is located in the center of the dipole and is ~0.25 microns. The device on the right is an example of a 10 micron detector built specifically for polarization tuning.

The anticipated benefits of these devices is its capability to provide polarization and wavelength resolved imagery, at high frame rates, in a rugged and lightweight system without moving parts. The availability of this additional information will substantially enhance the passive sensor capabilities for real-time target feature extraction, countermeasure discrimination, and clutter removal. Tunable ACIRFPA's will also facilitate the development of compact no moving parts hyperspectral imagers and imaging polarimeters.

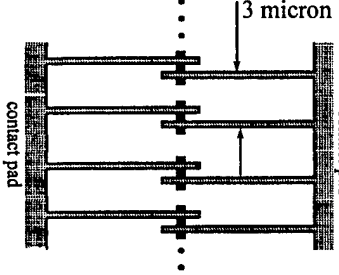
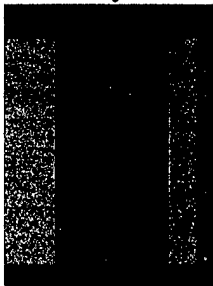


Unclassified
**Antenna Coupled FPA
Status**





- Bolometer-coupled dipoles have been fabricated
- Demonstrated response in the 8- to-12 μ m band
- Fast response time demonstrated (276nsec)
- Demonstrated polarization tuning over a 90° range
- Measured fringe-field collection area for dipoles and bowtie antenna patterns
- Development of well-defined modeling procedures, with good correlation to measured data
- Wavelength tunable device under development
- Patent application submitted through UCF for polarization and wavelength tuner
- Antenna coupled arrays currently being fabricated
- Technology Transfer:
 - UCF teaming with Lockheed-Martin (Orlando) to demonstrate antenna coupled technology on existing FPA silicon multiplexer

Unclassified

D:\VSTEF\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 14

Bolometers (0.25 microns) coupled to dipole antennas have been fabricated and demonstrated response over the 8 - 12 micron band. These devices have demonstrated very fast response times (<276 nanoseconds) and polarization tuning.



Antenna response patterns have been measured and were shown on the previous chart.

Models for predicting the performance of these devices is being developed and compared against measured results. This model will be used to optimize the antenna design. Current antenna designs are simple dipoles, however, future efforts will begin optimizing the design for the required functionality.

A wavelength unable design has been developed and is in the initial stages of fabrication.

Also in the initial fabrication stage is an array device, shown at right, where multiple antenna coupled devices are coupled together to form an integrated detector. Due to their small physical size, subarrays of these devices will make up each traditionally sized pixel in a focal plane array. This would allow the capability to have multiple fixed polarization or wavelength responses at the pixel level using these devices.


Lockheed-Martin has expressed an interest in this technology as an alternative uncooled IR detector. CREOL has teamed with Lockheed-Martin to develop and demonstrate fabrication of ACIRFPA's on a QWIP FPA silicon multiplexer.

	Unclassified Holographic Material Program	 Systems Center San Diego
<p style="text-align: center;">OBJECTIVES</p> <ul style="list-style-type: none"> ● Develop new photosensitive glass for use as a thick media for recording volume holograms <ul style="list-style-type: none"> ● Centimeters in depth ● High resolution (>3000 lines/mm) ● Permanent ● High Homogeneity ● Long term stability and durability ● Inexpensive ● Holographic glass could then be used to replace existing optics and potentially combine functions currently filled with multiple optical elements 	<p style="text-align: center;">APPROACH</p> <ul style="list-style-type: none"> ● Developed special glass using "standard" (pure) silicate glass doped with Ce, Ag, and F ● Holograms are written using UV laser and cured at elevated temperature (500°C) <ul style="list-style-type: none"> ● UV laser causes photo-ionization ● Thermal cure creates nano-crystallization which produces a refractive index variation 	<p style="text-align: center;">POTENTIAL APPLICATIONS:</p> <ul style="list-style-type: none"> ● Narrow band filter ● Wavelength division multiplexer / demultiplexer ● Hybrid holographic/refractive elements ● Holographic data storage ● Laser beam scanning
Unclassified D:\STEP\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 15		

The objective of the proposed research program is to develop volume holographic optical elements with new photosensitive glasses as the recording medium for beam shaping, optical data storage, spectral filters, and other applications. We have recorded high spatial frequency (3000 lines per mm), high diffraction efficiency (90%), high angular selectivity permanent multiplexed holograms with thermal stability making possible very high density data storage. The ability to machine Photo thermal refractive (PTR) glass into arbitrary shapes offers the potential for exciting novel applications in hybrid phase holographic/refractive optical elements and in volume data storage.


PTR glasses are silicate based glasses doped with transition metal, rare earth and fluorine ions which change refractive index when exposed to UV light followed by thermal processing. Holograms are written using a UV laser which causes photo-ionization. Following this the second stage is a thermal development which causes nano-crystallization thereby creating refractive a index change in the exposed areas.

Potential applications of these holographic glasses include: narrow band filters, wavelength division multiplexer, holographic beam storage and beam steering devices. The next chart illustrates these applications.



Unclassified


**Holographic Gratings In PTR Glasses:
Current Status**

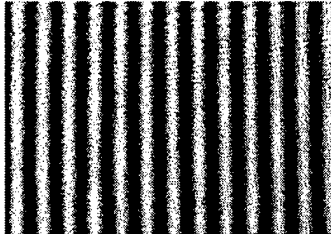


Systems Center
San Diego

GLASS FABRICATION & CHARACTERIZATION

- Technology of melting homogeneous PTR glasses in 400 cm³ crucibles has been developed. Refractive index variations in as-melted glass are below 10⁻⁵ in 1 cm² specimen (see interferogram).
- Technology line for grinding, polishing, and thermal development has been established.
- Optical homogeneity and induced refraction testing setup with sensitivity 10⁻⁷ has been developed.






BRAGG GRATINGS FABRICATION & CHARACTERIZATION

- Photosensitivity has been demonstrated
 - Writing laser: He-Cd, 325 nm, 1 mW
 - Exposures: 50 to 2500 mJ/cm²
- Volume gratings thickness: 0.2 to 5 mm
- Characterizations:
 - Absolute diffraction efficiency: up to 93 %
 - Angular selectivity: down to 0.2 mrad
 - Spatial frequency: up to 10,000 mm⁻¹
 - Mirror for $\lambda=325$ nm, w/ $\Delta\lambda<0.1$ nm & R>12 %
 - Measured laser damage threshold Of ~10 J/cm²

Unclassified D:\STEF\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 16


The current status is: we have successfully developed the materials mix and process to make this holographic glass in small sizes with very good results (i.e. high homogeneity), we have also developed the processes to cut and polish glass blanks out of the raw materials, photosensitivity of the material has been demonstrated and quantified and the thermal development process has been established.

Several commercial lasers operating in the near UV region, such as N₂, Ar, He-Cd, etc., can be used for recording. Reflective and transmitting Bragg gratings with spatial frequencies up to 10000 mm⁻¹ (100 nm period) were recorded in this glass. No restrictions exist in the range of low spatial frequencies. Absolute diffraction efficiency above 90 % was obtained for visible and IR regions. Only several tens of mJ/cm² are necessary to achieve such efficiency. Mirror for $\lambda=325$ nm with $\Delta\lambda<0.1$ nm and R>12 % was fabricated. Two-step process allows recording the several independent holograms in the same volume. Being developed, holograms in PTR glass cannot be destroyed by the further exposure to IR, visible, and UV radiation. Bragg gratings in PTR glass are stable up to 400°C. Laser damage threshold is in the range of 10 J/cm² for nanosecond laser pulses. PTR gratings secure angular selectivity below 0.2 mrad and spectral selectivity below 0.1 nm in IR and below 0.01 nm in UV region.



Unclassified

OPTICAL TARGET CHARACTERIZATION PROGRAM SUMMARY



- **Optical Target Characterization Program Is Concentrated On Excellent Science and Engineering**
 - Innovative laser radar systems at ISTEf, CREOL and SPAWAR Systems Center San Diego
 - Multispectral plume collections (passive & active) and analysis
 - Antenna Coupled IR Focal Plane Array (ACIRFPA) technology development
 - Photo-thermo-refractive (PTR) Glass technology development
 - DEBI flight experiment to collect optical background data for high speed interceptors
- **Relevance To BMDO**
 - Data collections for MDAPS
 - THAAD
 - Navy TBMD (PMRF)
 - Red Tigris III
 - SM-2 Block IVA
 - Roving Sands (Cruise Missile)
 - Technology development with eye toward transition opportunities
 - New laser radar techniques/technologies for future interceptors such as DITP
 - Optical background data collection effort with DEBI flight impacts future high speed interceptors such as AIT
 - New surveillance or seeker sensor technologies such as ACIRFPA

Unclassified

D:\ISTEF\Briefings\OTC_AIAA99.ppt 22 July 99 CHART 17

The Optical Target Characterization Program is concentrated on excellent science and technology development projects: the ISTEf laser radar program is developing new techniques and technologies in the area of laser radar; the Plume characterization program has developed the capability to collect highly resolved calibration multispectral data which is being used to compare against existing models; the new ACIRFPA technology is showing great promise in the area of uncooled IR FPA's; the PTR Glass effort has demonstrated a unique volume holographic material with long life which has a number of applications; and the DEBI flight experiment will collect optical background data which is very important to the next generation of interceptors with optical seekers.

While pursuing technology development efforts, the Program is also balancing this with maintaining BMDO relevance by collecting data for MDAP's and other BMDO Programs. These data collection efforts are often opportunities to collect data with some of the new technologies under development. The technologies being developed under this Program also have potential as insertion into current/future systems as a Pre-Planned Product Improvement.